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A Review on Polymeric Wound Dress for the Treatment of Burns and Diabetic Wounds

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Abstract
Today, various commercial dressings have been developed and introduced to the market. The diversity makes it difficult for the nurse to choose the right type. Although the most important reason to use a wound dress is to protect the wound from infection and prevent infection, but in fact, the main purpose of using these materials is to speed up the wound healing process. Traumatic injuries result in an epithelial wound that disrupts the continuity of the skin surface. These differences reveal as abrasions, punctures, and injuries. Wounds are divided into two types; the skin is either cut or ruptured, including deep wounds and bruises, or surface wounds. Expedited wound healing has been considered since the archaic era of human civilization, with the earliest reported case from the Ancient Egyptians. Wound lesions in mummified humans were observed to be cover with animal skin, with signs of (primary/secondary) wound healing present. A "new wound dressing" is an advanced wound dress used in wound management as biocompatible and biodegradable biomaterials that heal wounds and burns. In the past, it was believed that dry wounds had expedited healing and wet wounds have been found to promote using re-epithelization and result in reduced scar formation. Wounds can be treated using various types of natural polymers and materials. Also, techniques like electrospinning and freeze-drying techniques can be used for the fabrication of standard wound dress. These wounds are associated with bandages, inflammation, bleeding, pain, and pus. In this work, we consider various types of wounds and techniques to treat the wound. Susceptibility to these areas, due to special symptoms for each of them. Products like hydrogels, hydrocolloids, films, sponges, and nano-fiber polymeric materials are used to promote healing. In this review, we examine the ideal products for the treatment of wounds in diabetic patients.
Keywords: Wound dressing, Hydrogel, Diabetic foot ulcers, Freeze drying, Medicine

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Introduction

The human skin is the outer covering of the body and is the largest organ of the integumentary system.[1,2] The internal infrastructure to remain undamaged from external factors and protects external infectious pathogens from affecting the internal organs and tissues.[3-7]

Hair and nails originate from the skin and provide additional protection.[8] The appearance of the skin varies widely; this change is not only due to non-modifiable factors such as race or aging, but also reflecting emotional fluctuations and systemic health.[9] However, the living cells of the skin are constantly produced in the subfamily of the rupture to replace these damaged cells.[10] As shown in Figure 1,[11] under the rupture (epidermis), the dermal layer contains blood vessels, nerve endings, and endocrine glands. Skin constantly restores the stratified squamous epithelium through the loss of dead cells and the production of new cells.[12] As a result, epithelial cells that are lost due to wear, damage, or disease are quickly replaced.

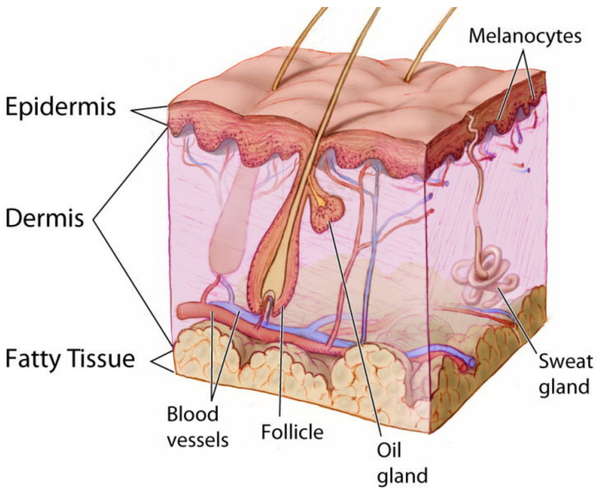

Figure 1. Different skin layers including epidermis, dermal and lipid cells.[10,11]

New keratinocytes are formed in the stratum basal which is the deepest layer of the epidermis then are shed to the outer layers.[13] The disappearance of the contiguity of body tissues, both inside and outside the body, is called an ulcer.[14] In other words, all external trenchant things will damage any soft tissue parts.[15] The repair occurring the in skin will, in primary wound healing, spontaneously close the wound cite leaving minimal scarring in the process.[16-18]

As the base of the wound traverses the dermis and subcutaneous tissue, there is an increased likelihood of scar formation after primary or secondary closure; on occasion requiring surgical intervention to alleviate the extent of the fibrosis.[19] Other factors such as the extent of tissue damage as well as the location of the laceration.[20] There is a variation in wound healing rates between individuals as well.[21,22] In other words, ulcers can be divided into two categories such as non-infectious wounds in which the wound occur accidentally and accidentally under clean conditions and do not cause an infectious problem for the patient. To discuss the infectious wounds, there is a microbial agent in the wound.[23] Pain is the classic presenting complaint, and infected wounds typically contain thick, pustular, and serosanguinous secretions and, if not addressed promptly, the infection spreads to the surrounding tissue and can cause sepsis.[24] It is commonly stated that the only two pathologies that can be visualized are anthrax and jaundice that can be easily recognized by their appearance.[25,26] A skin infection caused by staphylococcal spp. as well as Streptococcus pathogens. It presents in children with a sore that ruptures within a few days and a characteristic "honey crust" covers the wound. Children have developing immune systems and with decreased attention to hygiene, these pathogens tend to target children more often.[27] The agent is a bacterium called basil anthrax. The disease is more common in people who live alongside livestock (with direct zoonotic transmission).[28] The characteristic ulcer with a central black Escher is transmitted directly from the patient's open wounds. Aside from cutaneous involvement, anthrax commonly presents with gastrointestinal and pulmonary involvement. Early detection and treatment prevent mortality.[29] Anthrax has a medical treatment, but not all cutaneous pathologies require medical management.[30] Vascular pathologies can cause both arterial and venous ulcer wounds on the lower limbs due to decreased blood perfusion to the peripheral tissues.[31-34] The main purpose of this study is to review of methods and techniques for fabrication of novel wound dress for burns and diabetic wound. Venous ulcers present in those with a history of venous incompetence. To improve these wounds, various techniques such as oxygen therapy, dressing, or ozone therapy are used.

The History of Smart Wound Dressings

Before the nineteenth century, wounds were covered with natural materials such as linen, hemp, and cannabis. These wound dressings had some disadvantages despite being absorbent. For example, these natural materials often did not keep the ulcers wet, causing inflammation and infection as a result of adhesion to the cite of the ulcer, and delayed the recovery process.[10,34-37]

The core of this absorbent dressing was cotton that lay between two layers of linseed oil. Designed to be long-lasting, durable, and absorbent, this dressing is still used as an alternative to current methods. Sometimes it is also used in conjunction with alginate dressing.[18] Table 1 shows that some natural polymers used for wound dressing. Due to special medical conditions, many polymers cannot be used. This paper examines polymers that are most used in the manufacture of medical instruments. Table 2 lists some of the synthetic polymers, each of which has unique properties.[33-37]

A Compressive Review of Wound Dressing Methods and Techniques

The Electrospinning Method

The electrospinning method is used to generate a nonwoven web of micro- or nanofibers. This results in decreased nutritional support to the cutaneous aspects of the skin which causes breakdown of the skin and ulcer formations.[35] As shown in Figure 2,[36] venous ulcers are typically found along the malleoli and the dorsum of the foot. These wounds healing is slowly and they are often difficult to resolve completely. Special attention is taken to debride the ulcer, sterilize, and bandaged with topical emollients that expedite wound healing.[37] Arterial ulcers progress rapidly but are usually over the tibia proximal to the malleoli. The principles of care for arterial and venous ulcers are roughly the same, but the most important thing is to treat the underlying pathology.[37] Often venous

Table 1. Some Commonly Used Natural Polymers to Produce Wound Dressing[13-18]

Categories	Polymer	Description
Polysaccharide	Cellulose and its compounds	The polysaccharide cellulose compounds are the first used material as a wound that is used to improve chronic ulcers, reduce pain, and reduce recovery time.
	Alginate	Alginates are made up several polysaccharide chains. Alginates are used in the manufacture of wound healing and drug release due to coagulation properties.
	Dextran	The extra polysaccharide is made up of numerous glucose molecules. And as a replacement for the plasma to regenerate the body's fluid volume, after a lot of blood is lost.
	Chitosan and chitin	Refer to the text of the article.
	Hyaluronic acid	A type of glucose is amino glycan, found in vertebral tissue, and is a combination of glucuronic acid and N-acetyl-glucosamine. It is rapidly degraded in the body and is further injected into the gel.
Polysaccharide sulfate	Heparin and chondroitin	Heparin has a blood coagulation effect. Chondroitin, a combination of the chlorine steyocarnenic family, is a gelatinous substance present in the cartilage.
Protein	collagen	The most common protein is among the biomaterials. Used in soft tissue and plastic surgery.
	Fibrin	Blood coagulant is used for wound healing.

Table 2. Some Common Synthetic Polymers to Produce Wound Dressing[12-15]

Polymer	Description
Polycaprolactone	Due to the low degradability and high absorption of substances in drug release systems, it is used.
Polyglycolic acid	Biodegradable polystyrene that is used in medical applications.
Poly-lactic acid	Biodegradable polystyrene, which is degradable due to degradability, is used in its drug release system
Poly-lactic-co-glycolic acid	It is a polymer of polylactic acid and glycolic acid with special properties that are simply processed. Due to biodegradability in medical fields, the production of suture, drug release, and tissue engineering is used.
Polyvinyl alcohol	Polyvinyl alcohol polymer due to low protein solubility in water resistance Non-toxicity Biodegradability Non-carcinogenicity Influencing and biocompatibility are widely used in medical fields.
Polyurethane	Biodegradable thermoplastic, which has many uses, especially as a heart prosthesis.
Polio ortho ester	Due to its low biodegradability, it is used in drug release systems.
Polytetrafluoroethylene	It has excellent resistance to extreme heat and erosion, it also has a low friction coefficient, has high electrical properties and high abrasion resistance, and is used to make surface coatings, wounds, and vessel transplants.

wounds can be avoided by risk factor modification to the damaged vein.

In arterial ulcers, it may be necessary to consider a surgical approach if the symptoms are severe, but it is not uncommon to place the patient on antiplatelet therapy and modify risk factors to retain perfusion. The presence of polymers may change the viscosity, conductivity, surface tension, and other properties of the electrospinning solution, which are critical for the electrospinning process. Electrospinning produces a variety of nanofibres and microfiber from polymer, ceramic or composite solutions composed of polymer-nanoparticles, as well as melt materials. An electron supply, a high voltage power supply is used to generate an electrical charge in the solution flow of polymer melt. To produce nanofibers, one of the high-voltage power supply electrodes are connected to a polymer, the other solution to the ground or to a conductive collector.[17-25]

By passing the solution from the inside of the capillary tube, the fluid is drained from the tip of the capillary tube to the collector due to the electric field generated by the high voltage supply between the tip of the copper tube and the collector connected to the earth. Due to the fluid motion, the solvent is evaporated and filaments with a diameter below a micron are produced on the collector. Due to the interaction of electrical forces, fluid charge surface load, viscoelastic force, and surface tension, the spiral motion is induced to the charged fluid, and the resulting nanofibers are produced as a continuous layer.

Figure 2. An Intravenous Venous Ulcer.[33,35]

Freeze Drying Method

Freeze-dryers are used to remove solvents from the polymer's building and drying the specimens by creating a vacuum at -40°C to -58°C without composite degradation.[15] The process of removing moisture from a sample or frozen piece of vacuum is called lyophilization or freeze-drying. In the freeze-drying process, the frozen water contained in the unit is removed from the sample by sublimation. The submerged lube is sucked out of the drying chamber by a vacuum pump or a steam evaporator.[22-29] The heat required for sublimation is provided by conduction or radiation. The frozen water is sublimated at or below 0°C under a pressure of 627 Pa (0.6 mbar) or less. Freezing drying has two main steps such as freezing, and water vapor separation. In this process, water vapor separation is costly part of the process. The implementation of the freeze-drying method relies on this vacuum stage. The vacuum pump, in addition to removing submerged water from the environment, lowers the pressure in the vacuum chamber under atmospheric pressure. Removal of non-condensing gases reduces the resistance of the vapor to the condenser. As these gases reduce the efficiency of the freeze dryer, the vacuum pump used should be able to reduce the pressure of the vacuum chamber to a minimum of (0.5 mbar).[26-31]

Electrospray Method

This method causes putting nanoparticles wound dressing on the skin. Until the present time, an electrospinning technique was used to remove fibers from the inside of the liquid by using an electrical charge, but the production of fibers is directly hazardous to the body, thus, by returning to the basics, a spray device is used. The use of a spray-to-spray biodegradable materials on the tissue is very interesting and is viable in various medical departments. The purpose of the mass production of nanofibers is the rapid repair of the wound, without stitches, which should be pulled out of the skin and may result in damage to the tissues recovered. Nanoparticle wound closures are now being broken down after 42 days and are superior to stitches with a life span of about two weeks. Also, the acetone in nanofibers is completely evaporated before the wound is exposed, resulting in ultimate wound-free toxicity to the living being.[32-37]

Forcespinning Method

At the moment, most nanofibers are produced by an electrical device, which, in addition to the very slow production of fibers, has limitations involved including the solvent type and solvent concentration. Forcing spin has increased at least four thousand times the speed of nanofiber production and can produce nanofibers from high-density solutions. Also, due to high-speed production, there are no nozzles in this system. Due to the difference in electrical potential, the electrical system causes a change in the nature of the polymer, which is a very important problem in some applications. In spurting forwards, due to its specific parameters, it does not only change the nature but also uses the intrinsic properties of matter to produce nanofibres. Dermatological injuries include mainly chronic ulcers, burns, tumors, and cuts, and traditional dressings by creating a dry environment that can delay the wound healing process, while the wound bed needs a healthy and healthy natural environment for repair. This problem was that traditional wounds would be replaced by new generation dressings. Figure 3a shows the porous nanocomposite wound sheaths that have been naturally biodegradable using a new method of homogenization of nanoparticles. The polymer has been synthesized utilizing seaweed, and the dressing produced can be used for both wet and dry wounds. Hydrogels such as chitosan and sodium alginate are used to make the injectable preparations. Chitosan has the ideal structure for cell encapsulation, and sodium alginate can form a hydrogel in physiological conditions, a gentle gel decomposition for cell retrieval, and a nutrient source for cell growth. One of the treatments for wounds is the use of absorbent wound dressing (Figure 3b), this wound dressing causes to controlling bleeding, prevents infectious sources from targeting the damaged tissue and therefore allows for expedited and complication free healing. In making this dressing, nanofibers can be mentioned as one of the materials. In this study, using the spin-forming force-forming machine, the production of quenched fiber was carried out by loading chemical and herbal medicine within the fibers. Figure 3c is a tool that prevents the infection from wounding by covering the wound, since the wounds are usually unique, individualized dressings can be produced. Affordability, accessibility, and a minimal side effect profile are the characteristics of the injured wounds, so that the tissue can be effectively treated, the wound environment must be ideal. The wound environment should remain hydrated as it prevents a delay in migration of the cells to the epidermis. The produced dressings are biocompatible, body tissues are easily stored within the dressing allowing for normal cellular development. In addition to the ability to protect the wound, biocompatible hydrogels are capable of absorbing wound secretions, while retaining the ability to exchange the air and maintaining non-adhesion to the wound cite or the restored tissue of the skin. Silk hydrogels made have been used due to the inherent fluid-absorbing grid structure, biocompatibility, as well as the possibility of destruction within the body. The resulting fibers in these studies are polyester fibers that have been engineered to increase biocompatibility by modifying the surface via silicon nanostructured hydrogels. These hydrogels are based on a three-dimensional biomimetic matrix and a porous network, thus providing the ability to load a suitable drug for wound treatment and enhancing

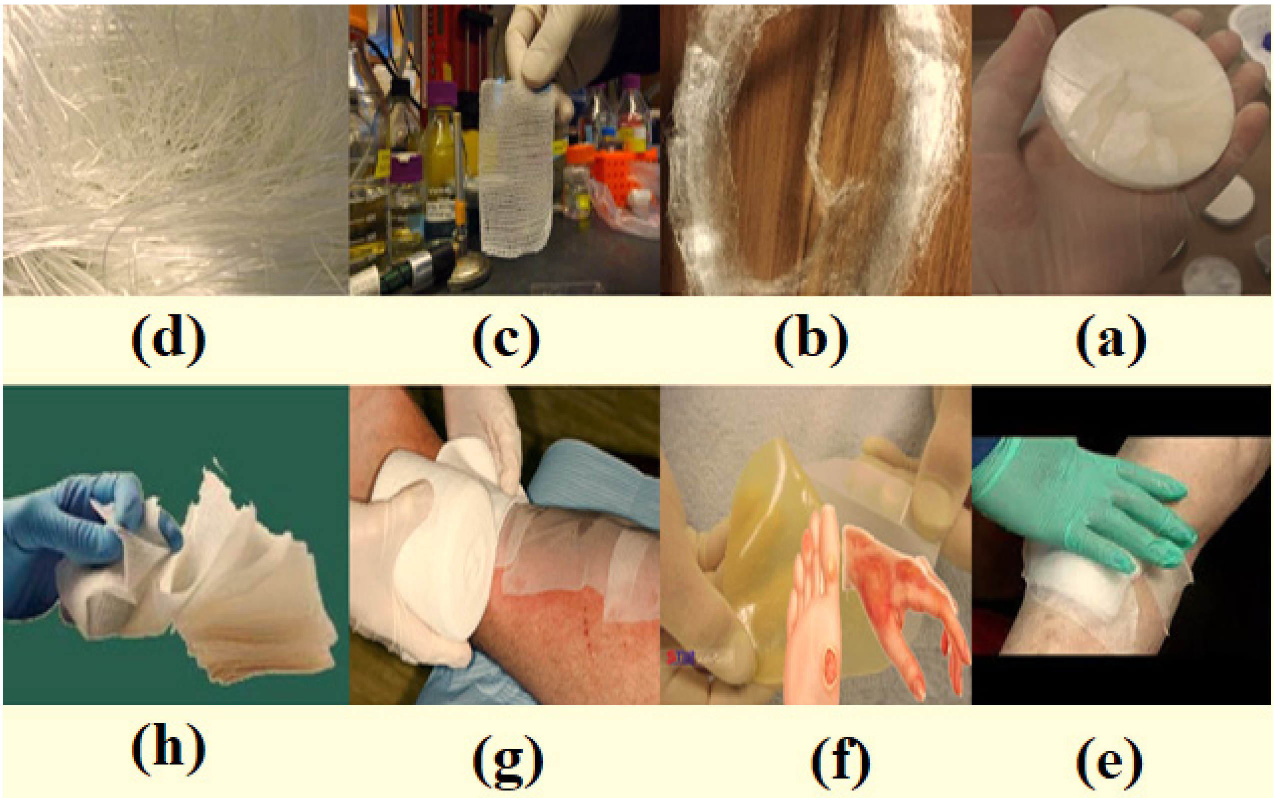

Figure 3. Introduction of Some Modern Wound Dressings Fabricated by Researchers, (a) freeze dried chitosan, (b) nylon wound bandage, (c) wound fabric dress, (d) fiber, 9e) wound dress on wound cite, (f) wound schematic, (g) fabric and wound dress, and (h) layer of fabric [33, 35]

cosmesis. The silicon fibroin hydrogel is structurally similar to the fiber fibroin silk, and these smart packs are supplied with the name PET-SILK (Figure 3d); characteristics such as high-water absorption and maintenance, increased surface-water conductivity, and catalyze loading of the active agent within the fibers. The absorption of water within this wound dressing has been made effective utilizing nanotechnology. The raw polyesters carry a low absorptive capacity and therefore hold a minute amount of water. By manufacturing the nano-hydrogel with silk, which has a three-dimensional matrix consisting of hydrophilic groups, the hydrogel in the polyester fabric has increased. The loading capacity of the active agent within the fibers of this dressing is due to the structure of the porous hydrogel in the PET-SILK fiber, allowing the loading of a variety of active agents, including antimicrobials, to create antibacterial properties in the final product. In this study, PET-SILK with antimicrobial extract of Salvia officinalis resulted in a 99% antimicrobial effect against bacteria, which indicates the benefit of *Salvia* extract as a natural and environmentally friendly antimicrobial agent in the improved wound healing properties. Nano-fiber electro spin technique was developed to add nano-fibers in addition to loading nanoparticles of silver. Figure 3e shows a wound that has antibacterial properties besides antibacterial properties. The nano-fiber property maintains a high surface-to-surface ratio that allows the drug to be applied over time and with great efficacy to the wound. The long-term efficacy of the drug is due to the biocompatibility of the polymer used to produce nano-fibers. Built-in polymer dressings have inherent biocompatibility while preventing adverse reactions in the wound or body. Healing can be expedited to repair wounds by inducing angiogenesis at the site of injury. The polymeric wound dressing is shown in Figure 3f has a controlled release capability of two anti-bacterial and anti-inflammatory drugs, and is based on the construction of this newly developed nanoparticle dressing. The two drugs are within the bilayer hydrocolloid films are loaded, and controlled release of the substances are implemented to the wound cite. The drug was exposed to the ulcer within the first 24 hours of antibacterial activity and removed, after which the release of antibacterial agents continued for up to 48 hours. After 48 hours, the anti-inflammatory drug begins with its release lasting up to 96 hours. The unique benefit of this dressing is the controlled release formulation since its antibacterial release in the first 24 hours prevents infection, and the anti-inflammatory drug expedites healing. The biological properties of this dressing are perfectly suited to various types of ulcers and the mechanical aspects are such that they can remain intact for several days to release the drug on the wound. This kind of wound dressing shown in Figure 3g is synthesized from alginate (a natural polymer extracted from algae), this study focused on biocompatibility, size fluctuations, and absorption effects. Researchers also focused on the effects on the growth, reproduction, and migration of skin cells from the examined cases of their ulcers. This dressing was tested in vitro on various cell lines. When compared to the all samples have seen cell growth, proliferation, and migration of the fibroblastic cells. This dressing can also inhibit the proliferation of bacteria within the wound cite, and thus, it can prevent infections of the wounds. This wound dressing is fabricated for deep wounds. As shown in Figure 3h, the manufacturing process of this dressing involves petroleum-based polyurethanes. These products can also be made with alginate, which is derived from algae and replaces a significant portion of the petroleum products. The use of alginates inside the wound prevents pathogens from infecting the wound as well as induces a rapid repair of deep wounds and ulcers from third-degree burns.

Conclusion

At present, 418 million people have diabetes, 200 million of whom are women. The statistics will reach 629 million by 2045. With the increase in diabetic cases, diabetic wounds also increase. Therefore, the construction of wound management principals has been increasingly researched and the demand for products that target these conditions is rising. New wound dressings have the ability to control secretions and expedite healing, due to having substances that better adapt to the wound surface. Not all dressings are suitable for use, and the product used varies as the healing stages are satisfied. Wounds should be assessed at each stage and clinical decisions should be made as to the products used to adequately satisfy and create healthy environments for wound healing. The wound environment should remain hydrated as it prevents a delay in migration of the cells to the epidermis. The produced dressings are biocompatible, body tissues are easily stored within the dressing allowing for normal cellular development. In addition to the ability to protect the wound, biocompatible hydrogels are capable of absorbing wound secretions, while retaining the ability to exchange the air and maintaining non-adhesion to the wound cite or the restored tissue of the skin.

Ethical Approval

Not applicable.

Competing Interests

The authors have no conflict of interest to declare.

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References

1. Lopes MB, Rajasekaran R, Lopes Cançado AC, Martin AA. In vivo confocal Raman spectroscopic analysis of the effects of infrared radiation in the human skin dermis. Photochem Photobiol. 2017;93(2):613-618. doi:10.1111/php.12701
2. Bahramsoltani R, Farzaei MH, Rahimi R. Medicinal plants and their natural components as future drugs for the treatment of burn wounds: an integrative review. Arch Dermatol Res. 2014;306(7):601-617. doi:10.1007/s00403-014-1474-6
3. Farahpour MR, Mirzakhani N, Doostmohammadi J, Ebrahimzadeh M. Hydroethanolic *Pistacia atlantica* hulls extract improved wound healing process; evidence for mast cells infiltration, angiogenesis and RNA stability. Int J Surg. 2015;17:88-98. doi:10.1016/j.ijsu.2015.03.019
4. Farazin A, Aghadavoudi F, Motififard M, Saber-Samandari S, Khandan A. Nanostructure, molecular dynamics simulation and mechanical performance of PCL membranes reinforced with antibacterial nanoparticles. J Appl Comput Mech. 2021;7(2):1-9. doi:10.22055/jacm.2020.32902.2097
5. Kazeroni ZS, Telloo M, Farazin A, et al. A mitral heart valve prototype using sustainable polyurethane polymer: fabricated by 3D bioprinter, tested by molecular dynamics simulation. AUT J Mech Eng. 2021;5(1):109-120. doi:10.22060/ajme.2020.17450.5862
6. D'Agata AL, Roberts MB, Ashmeade T, Dutra SVO, Kane B, Groer MW. Novel method of measuring chronic stress for preterm infants: skin cortisol. Psychoneuroendocrinology. 2019;102:204-211. doi:10.1016/j.psyneuen.2018.12.223
7. Misra BB, Misra A. The chemical exposome of type 2 diabetes mellitus: opportunities and challenges in the omics era. Diabetes Metab Syndr. 2020;14(1):23-38. doi:10.1016/j.dsx.2019.12.001
8. Klama-Baryła A, Kitala D, Łabuś W, Kraut M, Szapski M, Słomski R. Is transgenic porcine skin as good as allogeneic skin for regenerative medicine? Comparison of chosen properties of xeno- and allogeneic material. Transplant Proc. 2020;52(7):2208-2217. doi:10.1016/j.transproceed.2020.01.109
9. Komatsu N, Saijoh K, Toyama T, et al. Multiple tissue kallikrein mRNA and protein expression in normal skin and skin diseases. Br J Dermatol. 2005;153(2):274-281. doi:10.1111/j.1365-2133.2005.06754.x
10. Yuan WH, Hsu HC, Lai YC, Chou YH, Li AF. Differences in sonographic features of ruptured and unruptured epidermal cysts. J Ultrasound Med. 2012;31(2):265-272. doi:10.7863/jum.2012.31.2.265
11. Alibardi L. Adaptation to the land: the skin of reptiles in comparison to that of amphibians and endotherm amniotes. J Exp Zool B Mol Dev Evol. 2003;298(1):12-41. doi:10.1002/jez.b.24
12. Weber A, Whipp S, Usenik E, Frommes S. Structural changes in the nuclear body in the adrenal zona fasciculata of the calf following the administration of ACTH. J Ultrastruct Res. 1964;11:564-576. doi:10.1016/s0022-5320(64)80082-4
13. Rausch MK, Karniadakis GE, Humphrey JD. Modeling

soft tissue damage and failure using a combined particle/continuum approach. Biomech Model Mechanobiol. 2017;16(1):249-261. doi:10.1007/s10237-016-0814-1

14. Biazar E, Beitollahi A, Rezayat SM, et al. Effect of the mechanical activation on size reduction of crystalline acetaminophen drug particles. Int J Nanomedicine. 2009;4:283-287. doi:10.2147/ijn.s5895
15. Biazar E, Rezayat SM, Montazeri N, et al. The effect of acetaminophen nanoparticles on liver toxicity in a rat model. Int J Nanomedicine. 2010;5:197-201. doi:10.2147/ijn.s5894
16. Hosseini SM, Shahrousvand M, Shojaei S, Khonakdar HA, Asefnejad A, Goodarzi V. Preparation of superabsorbent eco-friendly semi-interpenetrating network based on cross-linked poly acrylic acid/xanthan gum/graphene oxide (PAA/XG/GO): characterization and dye removal ability. Int J Biol Macromol. 2020;152:884-893. doi:10.1016/j.ijbiomac.2020.02.082
17. Holmer A, Marotz J, Wahl P, Dau M, Kämmerer PW. Hyperspectral imaging in perfusion and wound diagnostics - methods and algorithms for the determination of tissue parameters. Biomed Tech (Berl). 2018;63(5):547-556. doi:10.1515/bmt-2017-0155
18. Singer AJ, Hollander JE, Quinn JV. Evaluation and management of traumatic lacerations. N Engl J Med. 1997;337(16):1142-1148. doi:10.1056/nejm199710163371607
19. Shahgholi M, Oliviero S, Baino F, Vitale-Brovarone C, Gastaldi D, Vena P. Mechanical characterization of glass-ceramic scaffolds at multiple characteristic lengths through nanoindentation. J Eur Ceram Soc. 2016;36(9):2403-2409. doi:10.1016/j.jeurceramsoc.2016.01.042
20. Karimipour A, Malekahmadi O, Karimipour A, Shahgholi M, Li Z. Thermal conductivity enhancement via synthesis produces a new hybrid mixture composed of copper oxide and multi-walled carbon nanotube dispersed in water: experimental characterization and artificial neural network modeling. Int J Thermophys. 2020;41(8):116. doi:10.1007/s10765-020-02702-y
21. Maddah E, Beigzadeh B. Use of a smartphone thermometer to monitor thermal conductivity changes in diabetic foot ulcers: a pilot study. J Wound Care. 2020;29(1):61-66. doi:10.12968/jowc.2020.29.1.61
22. Gefen A, Ousey K. Update to device-related pressure ulcers: SECURE prevention. COVID-19, face masks and skin damage. J Wound Care. 2020;29(5):245-259. doi:10.12968/jowc.2020.29.5.245
23. Malekzadeh M, Abbasi-Rad S, Shahgholi M, et al. Design and validation of synchronous QCT calibration phantom: practical methodology. J Med Imaging Radiat Sci. 2019;50(1):157-162. doi:10.1016/j.jmir.2018.10.002
24. Abbasi-Rad S, Akbari A, Malekzadeh M, Shahgholi M, Arabalibeik H, Saligheh Rad H. Quantifying cortical bone free water using short echo time (STE-MRI) at 1.5 T. Magn Reson Imaging. 2020;71:17-24. doi:10.1016/j.mri.2020.04.014
25. Stanley JR, Amagai M. Pemphigus, bullous impetigo, and the staphylococcal scalded-skin syndrome. N Engl J Med. 2006;355(17):1800-1810. doi:10.1056/NEJMra061111
26. Pieper B, Sieggreen M, Nordstrom CK, et al. Discharge knowledge and concerns of patients going home with a wound. J Wound Ostomy Continence Nurs. 2007;34(3):245-253. doi:10.1097/01.won.0000270817.06942.00
27. Nichols RL, Florman S. Clinical presentations of soft-tissue infections and surgical site infections. Clin Infect Dis. 2001;33 Suppl 2:S84-93. doi:10.1086/321862
28. Stevens DL, Bisno AL, Chambers HF, et al. Practice guidelines for the diagnosis and management of skin and soft tissue infections: 2014 update by the Infectious Diseases Society of America. Clin Infect Dis. 2014;59(2):e10-52. doi:10.1093/cid/ciu444
29. Fada R, Farhadi Babadi N, Azimi R, Karimian M, Shahgholi M. Mechanical properties improvement and bone regeneration of calcium phosphate bone cement, polymethyl methacrylate and glass ionomer. J Nanoanalysis. 2021;8(1):60-79. doi:10.22034/jna.2020.1904843.1220
30. Ghadirinejad M, Atasoylu E, Izbirak G, Gha-Semi M. A stochastic model for the ethanol pharmacokinetics. Iran J Public Health. 2016;45(9):1170-1178.
31. Ghasemi M, Ghadiri Nejad M, Bagzibagli K. Knowledge management orientation: an innovative perspective to hospital management. Iran J Public Health. 2017;46(12):1639-1645.
32. Zolotukhin IA, Seliverstov EI, Shevtsov YN, et al. Prevalence and risk factors for chronic venous disease in the general Russian population. Eur J Vasc Endovasc Surg. 2017;54(6):752-758. doi:10.1016/j.ejvs.2017.08.033
33. Raisi A, Asefnejad A, Shahali M, et al. A soft tissue fabricated using freeze-drying technique with carboxymethyl chitosan and nanoparticles for promoting effects on wound healing. J Nanoanalysis. 2022;7(4):262-274. doi:10.22034/jna.2020.1895736.1196
34. Kurakula M, Rao GS, Kiran V, Hasnain MS, Nayak AK. Alginate-based hydrogel systems for drug releasing in wound healing. In: Nayak AK, Hasnain MS, eds. Alginates in Drug Delivery. Academic Press; 2020:323-358. doi:10.1016/b978-0-12-817640-5.00013-3
35. Raisi A, Asefnejad A, Shahali M, et al. Preparation, characterization, and antibacterial studies of N, O-carboxymethyl chitosan as a wound dressing for bedsore application. Arch Trauma Res. 2020;9(4):181-188. doi:10.4103/atr.atr_10_20
36. Khandan A, Doozandeh Z, Saber-Samandari S. Preparation of novel Arabic gum-C6H9NO biopolymer as a bedsore for wound care application. Acta Med Iran. 2020;58(10):520-830.
37. Shojaie S, Rostamian M, Samadi A, et al. Electrospun electroactive nanofibers of gelatin-oligoaniline/Poly (vinyl alcohol) templates for architecting of cardiac tissue with on-demand drug release. Polym Adv Technol. 2019;30(6):1473-1483. doi:10.1002/pat.4579